MANSFIELD

Deflection of Machine Tools under Stress

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DEFLECTION OF MACHINE TOOLS UNDER STRESS

BY

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

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ENTITLED DEFLECTION OF MACHINE TOOLS UNDER STRESS

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

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DEFLECTION OF MACHINE TOOLS UNDER STRESS.

Experience in the operation of machine tools soon leads the careful observer to the conclusion that machine tools deflect under the stress due to taking a cut on the work. This deflection in a well designed tool is a small quantity; but nevertheless, it effects the accuracy of the work and the life of the tool. The object of this thesis is to study the nature of the deflections, determine upon a method of measuring them, develop the method, and make what tests the time will allow. It was decided that the best solution of the problem would be an instrument which would make a continuous graphical record. It was the aim to have the instrument accurate to a ten thousandth of an inch.

A careful search of the technical literature did not bring to light any previous attempt to measure the deflections of machine tools. Attention was next turned to instruments used in civil engineering to measure the deflection of bridge members and track equipment. The only thing found which bore upon the subject was an occasional reference to P. H. Dudley's stremmatograph, an instrument designed, primarily, to measure the stress in a section of a rail as a train passes over the track. The only information on the instrument available in the journals was the statement that a recording needle made a graph on a phosphor-bronze plate, the graph was magnified and the ordinate determined. A number of the graphs were reproduced in the journals. Because of a lack of definite information on his instrument, a letter was addressed to Mr. Dudley.

In reply he gave a full description and history of its development and he enclosed a copy of his patent. Briefly stated, he determined the stresses in the rail by calculation from the ordinates of the graph. The graph measured the amount of compression or extension of a segregated and measured portion of the rail at a known distance from the neutral axis of the cross-section of the rail. The design of the instrument for this thesis was worked out and sketched before receiving Mr. Dudley's reply and it was not changed later. The only similarity between the stremmatograph and the instrument of this thesis is the general idea of making a graph on a plate directly, and reading the ordinates under a microscope. The difference between the two is evident when it is considered that the purpose of the stremmatograph is to determine stresses while this thesis design deals with deflections. The principle of Mr. Dudley's instrument is based on the amount of extension or compression of a known length at a given distance from the neutral axis. The design under consideration is based upon the deflection of the center of a segregated section relative to the two ends.

Before making the detail drawings and taking up the construction of the instrument, it was desired to determine approximately the amount of deflection and the rapidity of the vibrations. The Gray Planer (30" x 30" x 8') in the machine shop was chosen for this purpose. A very fine wire was stretched across the top of the cross-rail and supported at either end. A scale graduated to hundredths was placed under the wire at the center. A heavy cut was taken on a large slab of cast iron. The deflection

of the cross-rail moved the scale under the wire. By means of a magnifying glass a slight deflection was detected.

A further test of the cross-rail was made with an Ames Test Gauge made by the B. C. Ames Co., Waltham, Mass. A heavy bar of iron was placed in the openings in the housings and fastened securely with planer jacks. By means of clamps, the instrument was fastened to the bar in such a way that a deflection of the cross-rail would press the plunger of the instrument. The movement of the plunger in turn rotated a pointer which passes over a scale graduated to thousandths of an inch. The instrument was first placed against the top edge of the cross-rail. A reading of the instrument was taken and the planer was started on the cut. The pointer on the dial vibrated through an arc of about 30 degrees at a rapidity such that the pointer could be seen only in the middle of the arc. This was about one and one half thousandths from the reading taken before starting the machine. The instrument was then placed with the plunger against the lower edge of the cross-rail. A deflection of two and a half thousandths of an inch was obtained and it was in the same direction as the deflection at the top. The results obtained may represent either the points of maximum deflection or the average amount. The error due to inertia of the moving parts of the instrument; plunger, springs, pointer, etc., was unknown but probably was a large factor in the results. This test brought out the two main difficulties to be contended with, small deflections and very rapid vibrations.

With these two difficulties in mind the instru-

ment, properly called a Deflexometer, was constructed. It was made as universal as possible so that it might be used on all machine tools. It consists of a frame or back, on the front side of which are V-ways on which a carriage is moved in a vertical direction and it can be clamped rigidly to the frame by means of two clamp bolts. These bolts are constructed with am arm which brings the pressure directly over the V-ways and removes any tendency to distort the carriage. On this carriage is a second carriage which moves in a horizontal direction. It rests on suitable guides on the back and bottom and two springs on the top tend to cause the carriage to run true. The front of the carriage has a recess and clamps to hold a plate on which the graph is made. The size of the plate is one sixteenth by one by three inches. This size was chosen so that either a metal plate or a common glass microscopic slide could be used. The carriage is made to travel along its path by means of a small cord attached to one end of the carriage and the other end of the cord is wrapped around a small drum driven by the driving mechanism taken from a Columbia Phonograph. This has a centrifugal governor which causes the carriage to be moved with uniform velocity and the speed may be adjusted fast or slow according to the rapidity of vibrations. The deflections of the machine are transmitted through a straight rod to a plunger working vertically through a lapped hole in the top of the frame. The end of the plunger extends down in front of the plate and is fitted with a point to make the graph. Assembly and detailed drawings of the Deflexometer are included in this thesis.

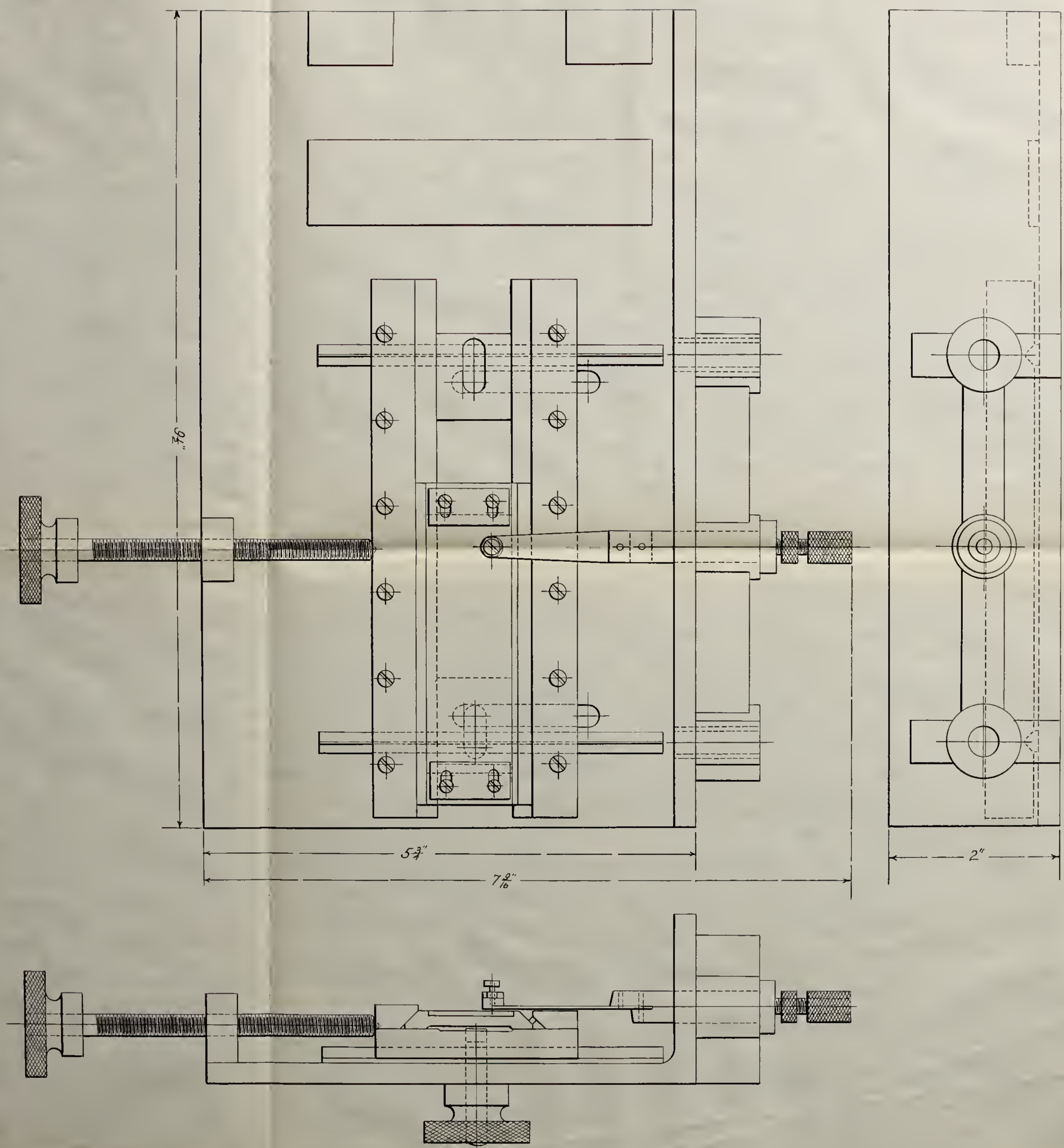
The Pratt & Whitney (16" x 7') lathe in the shop was equipped for the test. Two three inch channels, seven feet long were placed back to back and were bolted with spacing pieces to hold them three-fourths of an inch apart. Two cast iron blocks with tops of the shape of inverted V's were placed on the channel fifty-eight inches apart and the whole clamped solidly to the bottom side of the bed of the lathe by means of strap irons and bolts. The instrument was clamped to the under side of the channels at the center. A rod extending from the bed of the lathe was fastened to the plunger of the instrument. Considerable time and work was spent on the plate and recording point. The first attempt was made with a steel point working on copper. The point was of tool steel and was made very hard and ground to a sharp point under a magnifying glass. A plate was made of cold rolled steel and electroplated with copper. This method was tried twice but a smooth surface was not obtained and these plates were discarded. No sheet copper of the right thickness was obtainable so two thin pieces were soldered together. The plate was trued up on the surface grinder and polished. It was placed in the instrument and the point adjusted to make a very fine scratch. A test piece of steel 4" x 4' was placed in the lathe and a cutting tool of high speed steel was used so that a heavy cut could be taken. A base line was drawn on the plate by traversing the carriage of the Deflexometer past the point. The lathe was started and the carriage again moved across while the cut was being taken. The plate was removed and examined under a magnifying glass. It was found that

the edges of the scratch showed distinct vibrations and it indicated that the plunger had responded to the deflection while the rest of the instrument had remained stationary. The steel point on the copper proved to be too coarse for the work and the copper was too soft to receive an accurate record. It was decided to try a point of a very hard substance on a glass plate. A diamond chip, alundum and carborundum were considered. No diamond chips were available and the alundum proved to be too brittle. A crystal of carborundum was mounted in steel with hard solder, which came up around and protected the point. The pressure exerted on the plate by the plunger was borne by the solder and a graph of uniform depth was obtained. Records were taken in the same manner as before. The graphs were very faint scratches which were so fine that they could scarcely be seen with the naked eye.

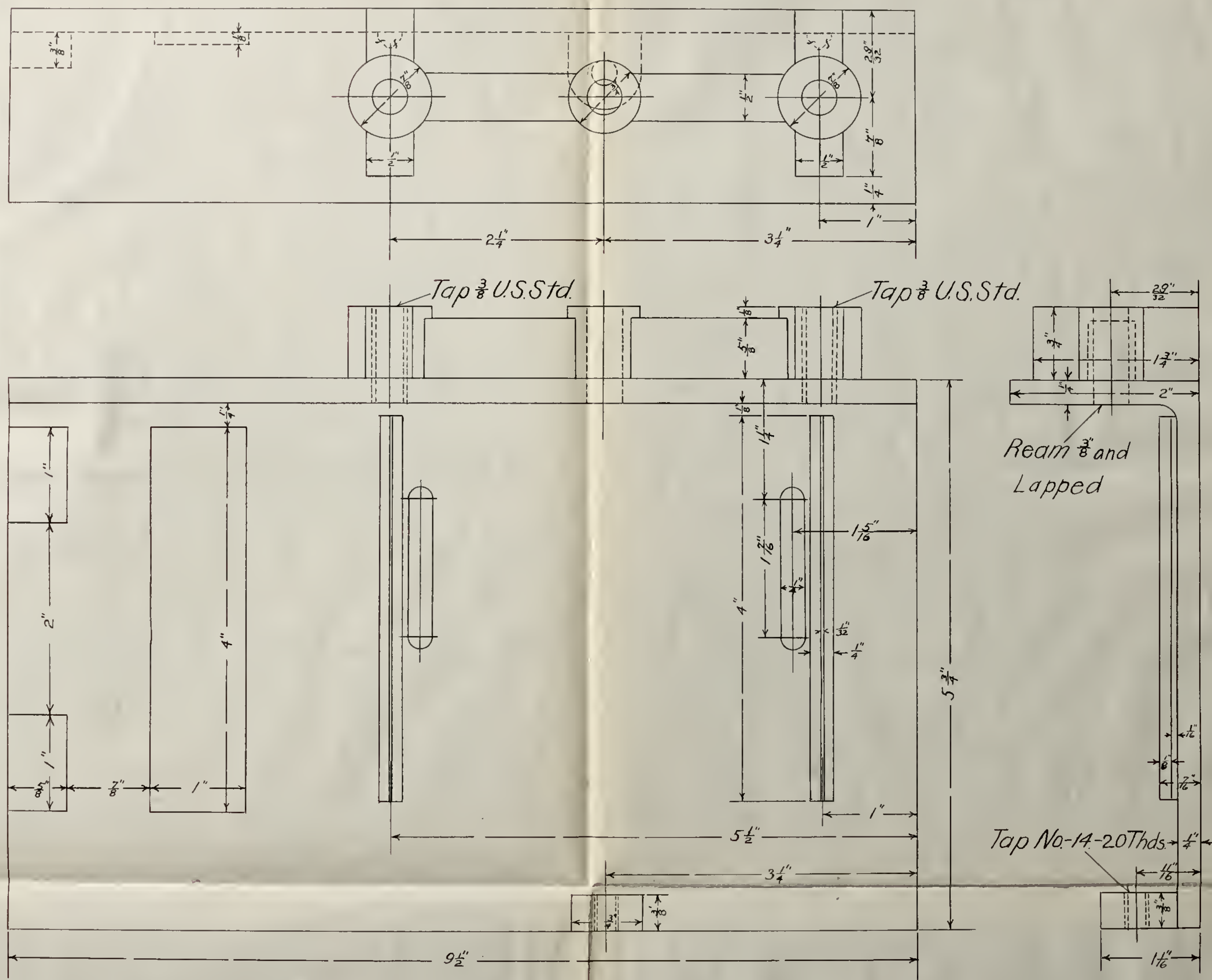
A high power microscope was used in reading the graphs, it was fitted with a micrometer attachment which projected fine graduations upon the field of the microscope. The microscope was calibrated with a micrometer slide having millimeters graduated to hundredths, this slide was placed in the instrument and the relation between the two scales of graduation obtained. The relation was found to be, 33 graduations equivalent to ten hundredths of a millimeter. The graph was put in place in the microscope and the ordinate between the base line and the deflection curve was read in a number of places. The average of these readings was taken and reduced to inches. The result obtained was 0.00165 inches deflection of the bed of the lathe in a span of 58 inches. Other graphs

taken at the same time and later checked closely with this value.

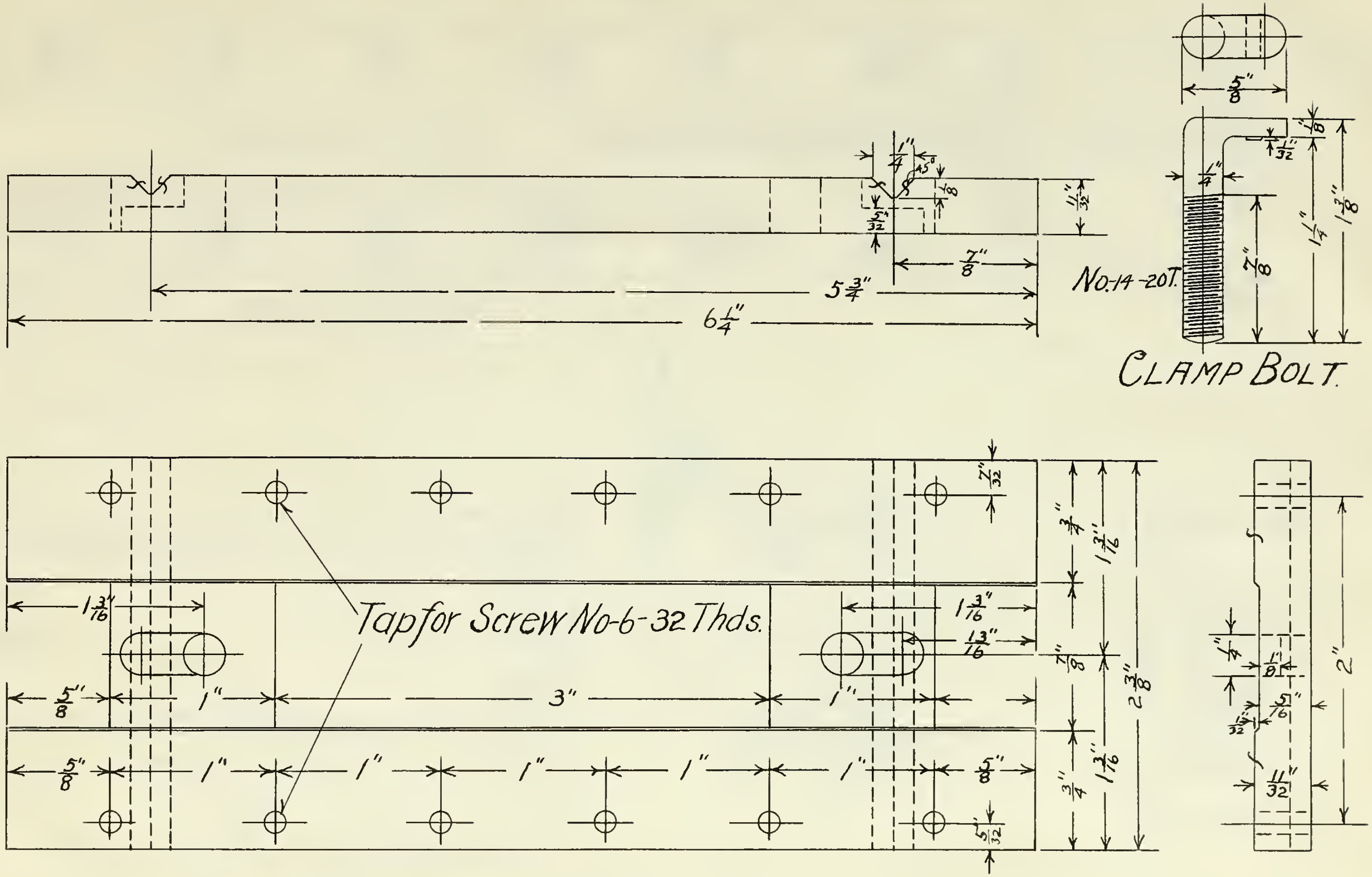
In conclusion it may be said that the results obtained are quite satisfactory considering that the thesis deals with a new field of investigation. It is regretted that time will not allow a more extended test of the Deflexometer this year. The subject is of value to the designer and builder of machine tools rather than to the user. It will aid in the solution of the problem of the distribution of metal. A comparison of the actual and the computed neutral axes in machine parts would give some interesting information. For future work on this subject of deflections, it is suggested that a series of tests be run on several lathes of the same size and different makes using constant conditions with regard to the test piece, tool and cutting speed. The effect of the floating of the core in a large C-frame could be obtained with the Deflexometer.



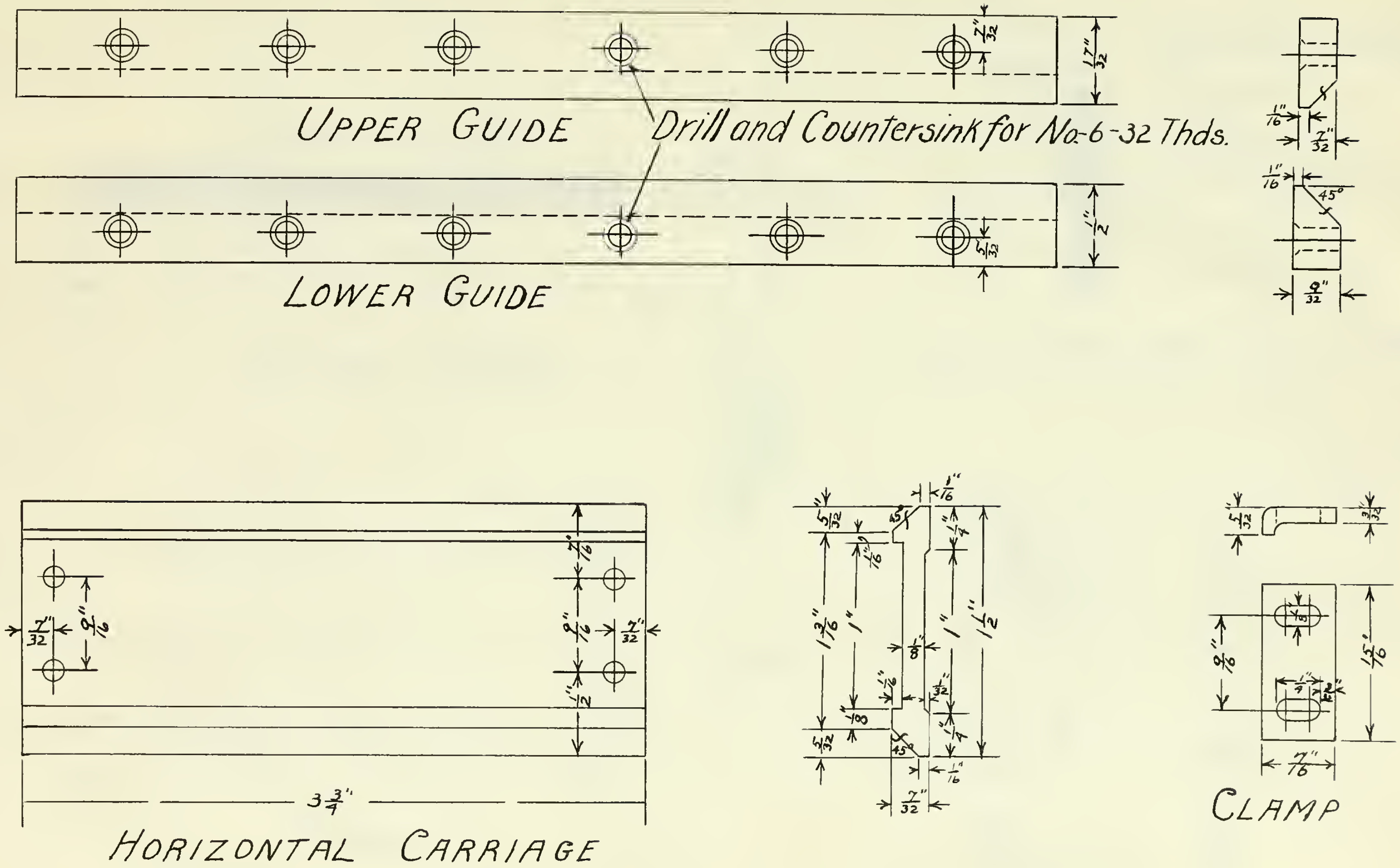
ASSEMBLY DRAWING OF DEFLEXOMETER.

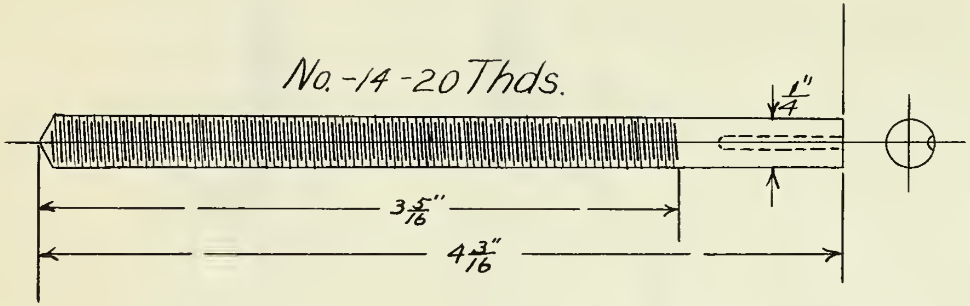


FRAME

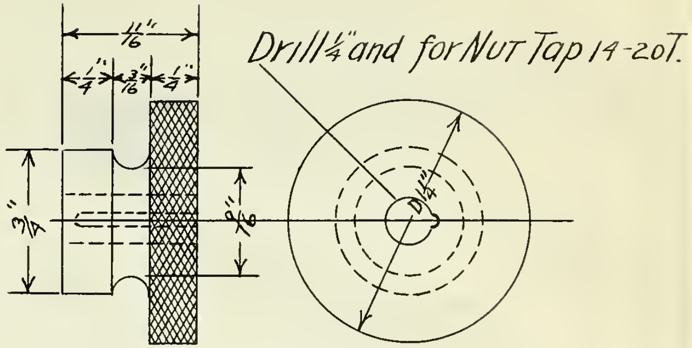


VERTICAL CARRIAGE


UPPER GUIDE
Drill and Countersink for No-6-32 Thds.
LOWER GUIDE
HORIZONTAL CARRIAGE
CLAMP



LIFTING SCREW.



SCREW HEAD AND CLAMP NUT.

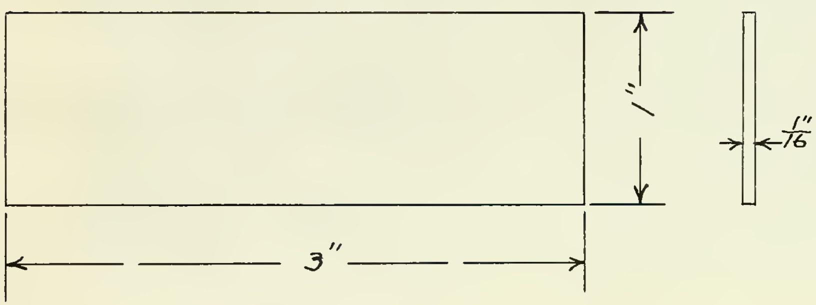
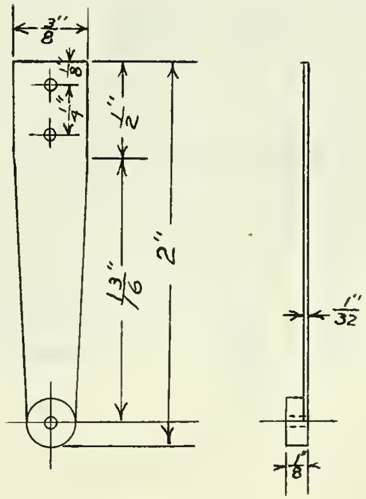
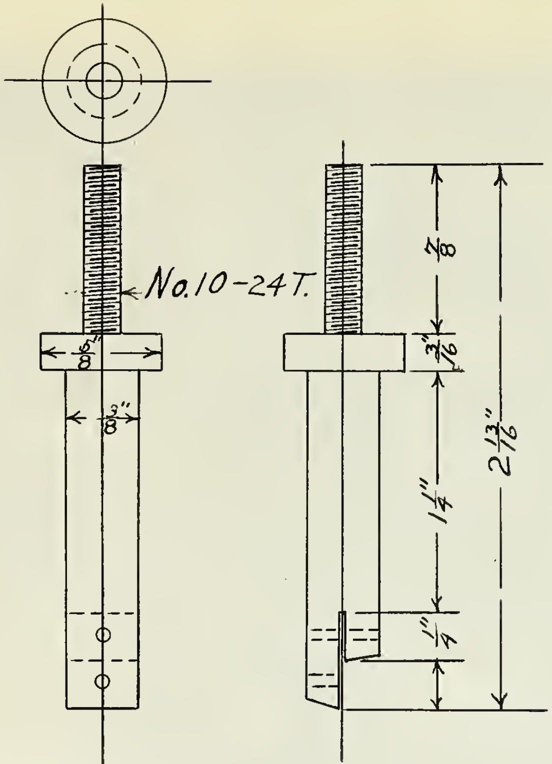


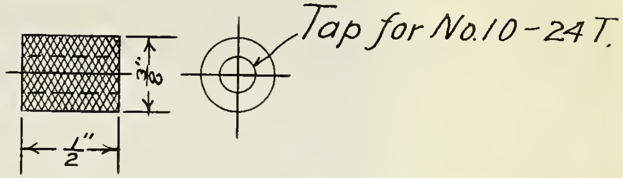
PLATE.



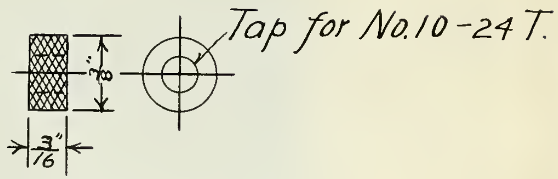
PLUNGER SPRING.



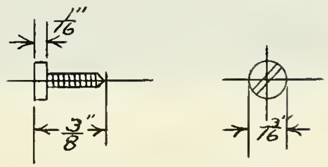
PLUNGER



PLUNGER NUT.



PLUNGER LOCK NUT.



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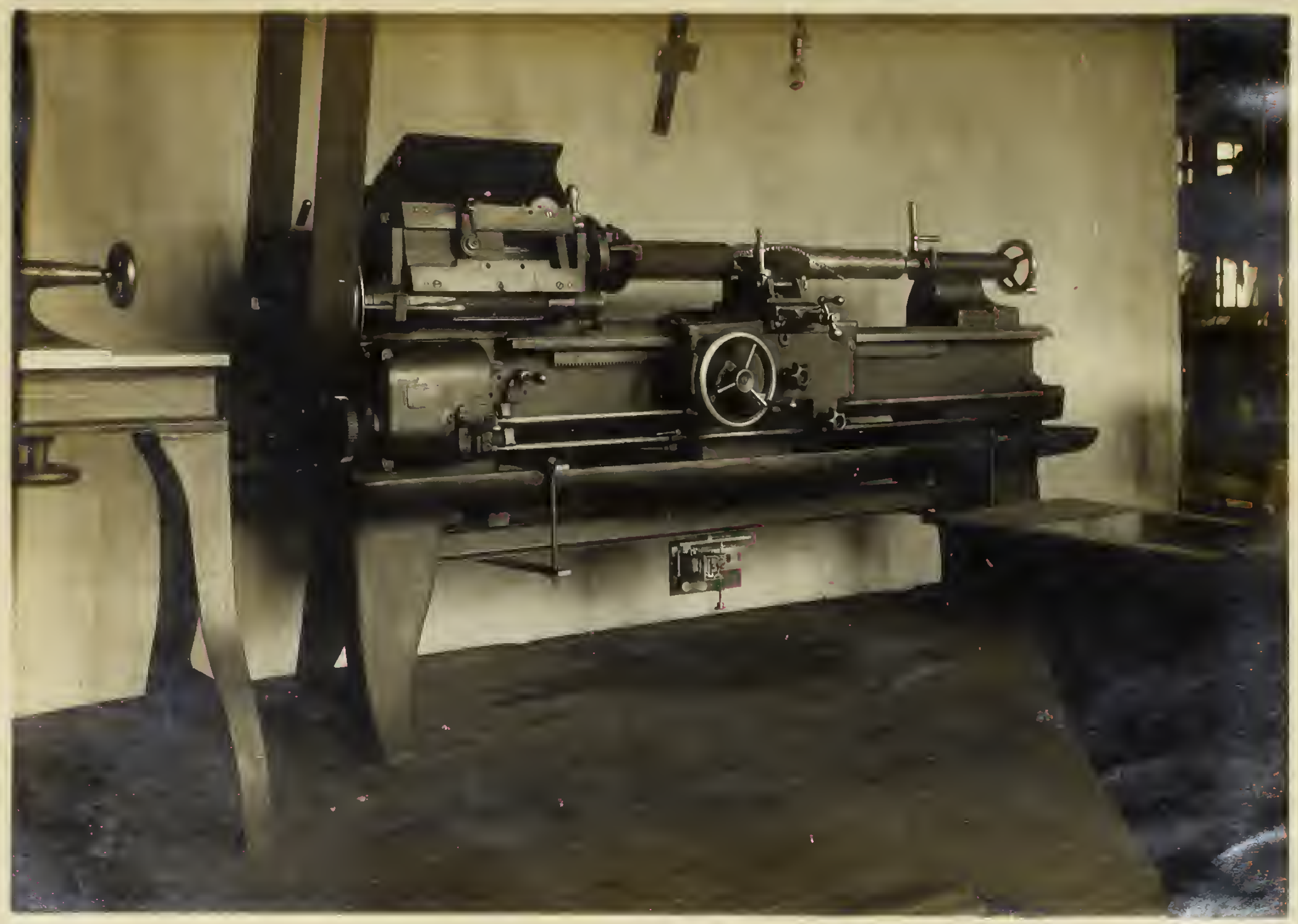
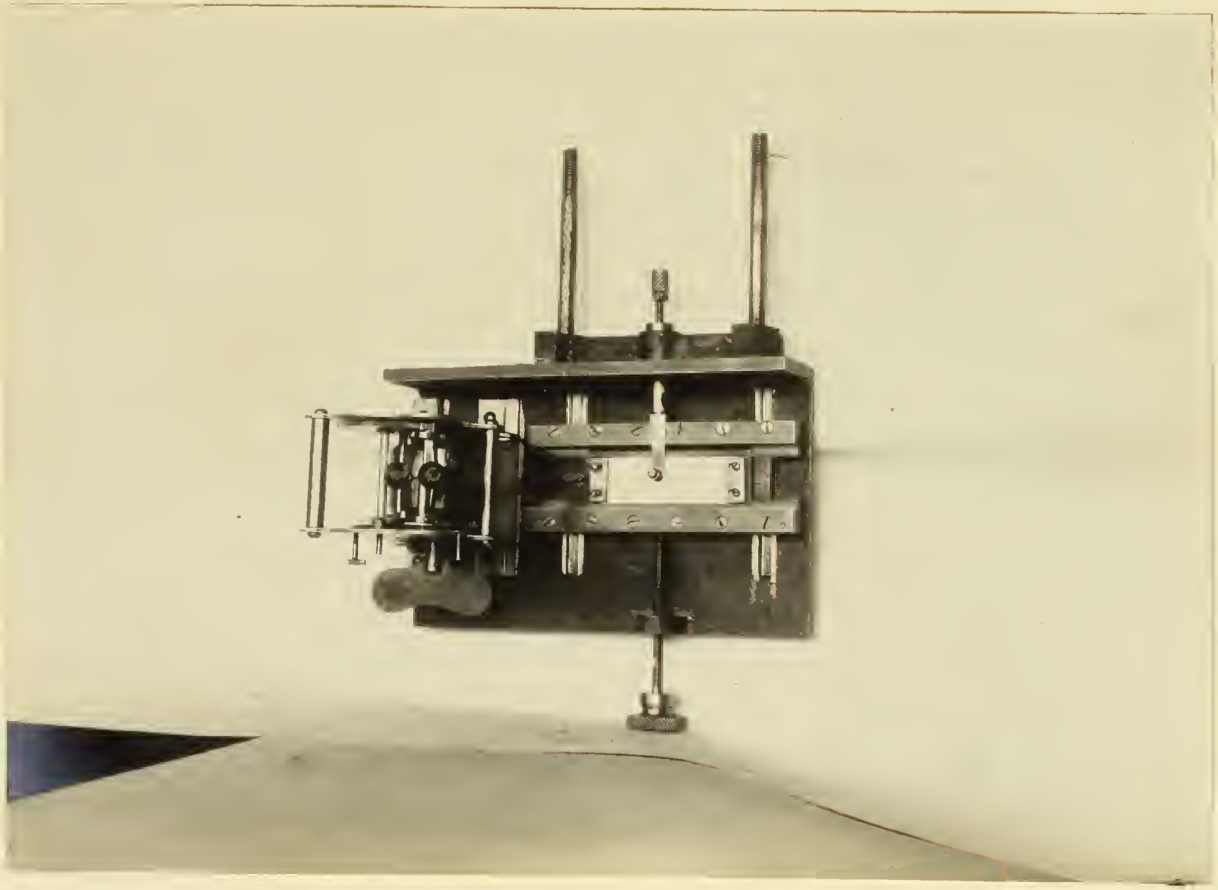


DEFLEXOMETER IN USE ON THE PRATT AND WHITNEY LATHE.



DEFLEXOMETER